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**ACTUAL VS SIMULATED EQUIPMENT FOR AIRCRAFT
MAINTENANCE TRAINING:
COST IMPLICATIONS OF THE
INCREMENTAL VS THE UNIQUE DEVICE**

By

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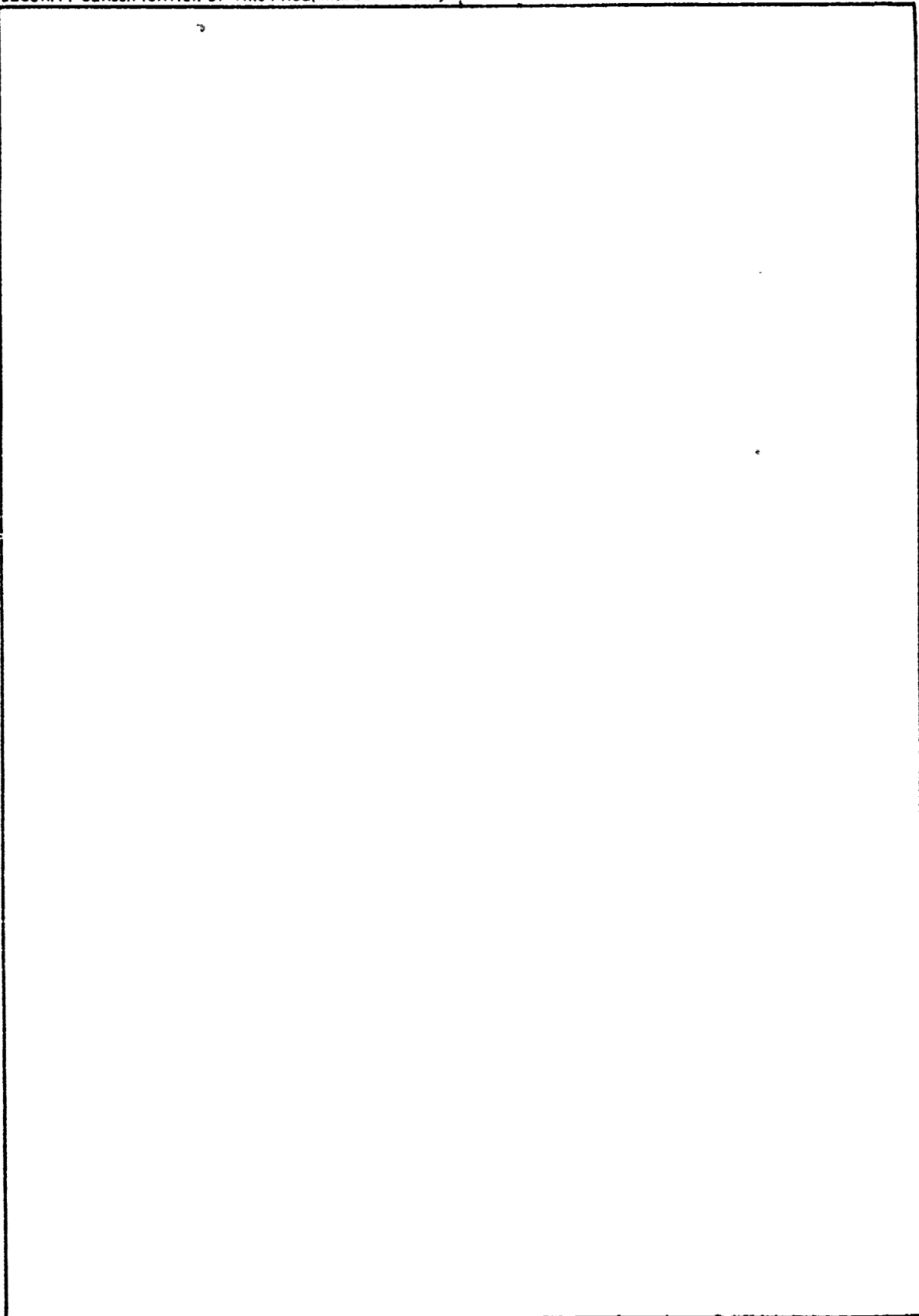
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ACTUAL VS SIMULATED EQUIPMENT FOR AIRCRAFT MAINTENANCE TRAINING:
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Life cycle cost estimates were developed for use of simulated test equipment vs actual test equipment in a maintenance training program of the type used for current advanced fighter aircraft. Previous life cycle cost comparisons had not explicitly considered the cost implications of procurement and support of a unique training device vs an incremental device. This effort included the unique vs the incremental device factor. Total estimated fifteen-year costs for simulated equipment trainers were significantly lower than comparable estimates for actual equipment trainers. The results indicate that the cost implications of a unique device vs an incremental device are important determinants of both acquisition and support cost estimates and should be considered fully in future life cycle costing efforts.

INTRODUCTION

Recent work has demonstrated that the use of simulated equipment for aircraft maintenance training may have advantages over training using actual equipment in such areas as training effectiveness, safety, and reliability (Miller & Rockway, 1975; Modrick, Kanarick, Daniels, & Gardner, 1975; Wright & Campbell, 1975; Daniels, Datta, Gardner & Modrick, 1975; Spangenberg, 1974). Another area of possible advantage for simulated equipment is cost, since

previous studies have shown that simulated equipment has typically been estimated to show a significant life cycle cost advantage over actual maintenance equipment when used for training (e.g., Daniels & Cronin, 1975; Eggemeier & Klein, 1978). However, previous cost estimates have not explicitly considered that actual equipment is typically an incremental procurement, identical to previously procured and supported equipment, whereas simulated equipment developed for training is a unique device which requires its own acquisition and logistics support system. This paper will explore the cost implications of the incremental vs the unique device for the type of actual and simulated training equipment that may be used for maintenance training on advanced fighter aircraft systems.

Equipment costs over the life cycle can be divided roughly into: (1) production costs and (2) operation and support costs. Each of these can potentially show differences between simulated and actual equipment.

Cost differences between simulated and actual equipment trainers have been estimated mainly from complexity differences between the two types of devices, with the less complex device typically estimated to show advantages both in production costs and in operation and support costs. The less complex device is invariably the simulated equipment. Thus, due both to lower production and operation costs, simulated equipment trainers can show a significant cost advantage relative to actual equipment used for training purposes.

However, a second factor other than complexity that can greatly influence cost is whether the device is to be a unique, one-of-a-kind procurement or whether it is an incremental item identical to many already procured. The

life cycle cost of actual equipment procured for training cannot be accurately estimated unless calculations take into account that the device is one of many that are slated for procurement. That is, cost of spares, modifications, and other logistical considerations are, for the most part, already "amortized" over the cost of all devices. There are, for example, no new cataloging or documentation costs for procuring a device whose components have already been supported in this manner. Therefore, the cost of an incremental device is the difference of the total cost for procuring N operational devices and the cost of procuring $N + 1$ devices including the training device. The life cycle cost of that additional device will be considerably less than if that device were a unique procurement.

On the other hand, a maintenance trainer using simulated equipment will typically be a unique, one-of-a-kind device procured only for training. Although the device may be considerably less complex and costly than actual equipment for training, certain of its support and procurement costs, such as cataloging, documentation, and acquisition management may be more than those for the incremental device whose support and procurement costs have been spread over many devices. The result is that some of the savings in production cost for the less complex but single non-production prototype device may be offset by the relatively or absolutely greater costs in supporting that device.

The implications of this second factor have been explicitly considered in the present paper, which presents hypothetical life cycle estimates for a less expensive but unique simulated equipment maintenance training device and for

the more expensive but incremental actual equipment, such as might be used in the maintenance of an advanced fighter aircraft.

METHOD

Training Equipment Options

The hypothetical actual maintenance equipment considered here was conceptualized to be analogous to that used in the intermediate level maintenance of current advanced fighter aircraft systems. In particular, the hypothetical equipment consisted of a number of highly sophisticated test stations designed to diagnose possible malfunctions in aircraft Line Replaceable Units (LRUs) which have malfunctioned on the aircraft and have therefore been brought to the test stations for repair. Typical technician performance on the test equipment consists of connecting the LRU to the test station and performing a series of tests using the station to "troubleshoot" the LRU in order to determine which subcomponent has malfunctioned and needs to be repaired. These tests on modern test equipment typically include either direct (under operator control) or indirect (automatic) computer software test. The actual test equipment complement consists of one each of several test stations and associated peripheral devices required to test each of the aircraft LRUs.

Simulated equipment for training was conceptualized using design principles similar to those used for the 6883 converter/flight control simulated station for the F-111 aircraft (Baum, Clark, Coleman, Lorence, Persons, & Miller, 1979; Miller & Gardner, 1975) and the methodology used by

Eggemeier and Klein (1978) in the conceptual design of simulated maintenance training equipment for the F-16 aircraft. This type of simulated equipment shows a high degree of structural fidelity, but includes only the structural and functional capability necessary to meet major training requirements. Thus, the simulated equipment may have actual equipment or equipment with high functional fidelity for those test station components on which major training requirements will be taught, but may have only photographic mockups for those station components which are unrelated to major training requirements. In general, from the student's viewpoint, the simulated equipment would appear to function as the actual equipment does, but the internal components would be considerably less extensive than those of actual equipment. For cost comparison, it was assumed that each of the test stations in the actual equipment complement would be simulated and that special computer software analogous to that of the actual equipment would also be included.

Cost Estimation Model

Estimation of the life cycle cost of the training equipment options was accomplished with the use of the Simulator Logistics Support Cost (SLSC) model developed by the Simulator System Program Office, Wright-Patterson AFB, Ohio. This model estimates a large number of the costs associated with equipment, including both production and operation and support.

Each of these major categories is broken down into subcategories. Production cost is broken down into system investment, support investment, industrial facilities, and update modifications. System investment includes the procurement cost of the training device itself and all other costs

associated with production or procurement of the device, including management of the acquisition program. Support investment includes all of the costs associated with establishment of a support capability for the training device, including acquisition of technical data, support equipment required to operate and repair the training device, and the cost of initial spares and repair parts. Industrial facilities include the costs of construction or modification of facilities to house the training device. Update modifications include costs of retrofit changes to the training device or support equipment during the device development cycle.

Operation and support cost is broken down into unit mission personnel, contracted unit level support, unit level consumption, installation support personnel, indirect support, logistics support, sustaining investment, and personnel acquisition/training. Unit mission personnel include the cost of pay and allowances for unit instructor, supervisory, maintenance, and clerical personnel. Contracted unit level support includes the cost of any contractual support for the device provided directly to the unit. Unit level consumption includes the costs of energy associated with use of the device and certain maintenance materials for the device. Installation support personnel include cost associated with personnel supporting the operation of the base and tenant organizations. Indirect support includes miscellaneous support personnel costs not accounted for by other cost elements. Logistics support includes costs associated with the personnel, materials, and contractual services required to perform training device, support equipment, and device software material management, and material distribution maintenance, at the depot

level. Sustaining investment includes the cost of replenishment spares, modifications, and replacement support equipment. Personnel acquisition/training includes certain variable costs associated with personnel acquisition and training.

The SLSC model computes costs in these categories by two basic methods. First, actual cost data can be input into categories for which the data are available. Second, if actual data are not available, the model will estimate costs for that category based on functional relationships derived from relevant historical data.

The SLSC model was developed to estimate costs of aircrew training simulators, and as such required some modification to be appropriate for estimating cost of maintenance training equipment. These modifications required comparison of the specifications of prospective maintenance training equipment options to the specifications of the aircrew simulators in the areas of computer capability, type of student station, type of instructor station, linkage, and other components. The inputs for the training device options were estimated with support from Simulator System Program Office personnel to reflect the complexity differences between actual and simulated training equipment. The inputs reflected approximately five times greater complexity for the actual equipment.

The major estimated cost input, the production cost, was estimated at \$5.192 million (M) for the actual equipment. Cost for the simulated equipment was estimated at \$2.282M.

Although reliability on hypothetical devices cannot be represented

directly, the model allows inputs that will impact on reliability, and therefore on operation and support costs. It was assumed that each training device would be in operation 96 hours per week. However, it was assumed that due to the much greater complexity of actual equipment, nine non-instructor maintenance personnel would be necessary for an actual equipment trainer, compared to two maintenance personnel for simulated equipment.

Finally, to assess the cost of the incremental vs the unique device, cost for the actual equipment was computed as the life cycle cost difference between a hypothetical 36 actual equipment test stations, including the device to be procured for training, and 35 actual test stations, if the training device were not procured. However, the life cycle cost of the simulated test station was computed under the assumption that it was a one-of-a-kind device procured for training only.

The life cycle was assumed to be 15 years.

RESULTS

Table 1 presents SLSC model estimates for the incremental life cycle cost of actual equipment for training and for the life cycle cost of the unique simulated training equipment. Although the system investment cost of the simulated equipment (\$2.282M) is 44% of that of actual equipment (\$5.192M), the life cycle of simulated equipment is 59% of that of actual equipment. The percent increase is due in part to a very large absolute cost advantage for incremental equipment in support investment (\$0.665M for incremental equipment; \$3.776M for simulated equipment) which brings total production

costs for the devices to virtual equality. In addition, there was a large relative advantage for the incremental actual equipment over the unique

TABLE 1

Simulator Logistic Support Cost Model Estimates (in Millions of Dollars)
of Actual and Simulated Maintenance Training Equipment

Cost Category	Training Equipment	
	Actual Equipment	Simulated Equipment
System Investment	5.192	2.283
Support Investment	.665	3.776
Industrial Facilities	.000	.000
Update Modifications	.670	.316
Total Production Cost	6.527	6.374
Unit Mission Support Personnel	4.066	.650
Contracted Unit Support Personnel	.000	.000
Unit Consumption	.452	.013
Installation Support	.655	.065
Indirect Support	.497	.052
Logistics Support	2.334	.727
Sustaining Investment	4.390	3.847
Personnel Acquisition/Training	1.369	.182
Total Operation and Support	13.763	5.536
TOTAL LIFE CYCLE COST	20.290	11.910

simulated equipment in sustaining investment. Sustaining investment for the actual equipment was 85% of system investment, whereas sustaining investment for simulated equipment was 168% of system investment.

DISCUSSION

The results indicate that although simulated equipment shows a significant system cost advantage over the more complex actual equipment, part of these

cost advantages are offset by the higher cost of supporting a unique, but less costly, device relative to the incremental cost of supporting a more costly device identical to many that have already been procured and supported. Typically, it has been estimated that simulated equipment for training would be less expensive than actual equipment used for training. The present results do not contradict these findings and in fact, support that general conclusion for the specific parameters investigated here. However, the results suggest that the cost advantages of simulated equipment are not as great as may be assumed if costs of both devices are estimated as if each is the only device to be procured.

Although based on a hypothetical system with the specific characteristics that have been stipulated, the results suggest that if certain conditions are present, the cost advantage for unique simulated equipment may be lessened further. One of these conditions is system cost. If the simulated equipment costs were increased relative to actual equipment, then the cost of supporting that device, especially the cost of support investment, would increase the life cycle cost to a greater relative degree than only the system investment cost. A second condition is number of actual equipment devices procured. If more devices are procured, the incremental cost of the $(N + 1)$ device will be less. Finally, although the total support costs (support investment plus total operation and support) are substantially less for simulated equipment, this is somewhat a function of the assumed 15 year life cycle for the system. A different assumed life cycle, say 7.5 years, would have produced much more comparable total support costs. Specifically, for the assumed 15 years life

cycle the total support costs for the actual equipment is \$14.428 M, and for the simulated equipment is \$9.312 M. However, for an assumed 7.5 year life cycle the total support costs for the actual equipment is \$7.546 M, and for the simulated equipment is \$6.544 M. If all of these conditions were present, the life cycle cost of unique simulated training equipment could approach parity with the incremental actual equipment trainer.

Confidence in the results presented here rests mainly on the degree to which the SLSC model can accurately estimate actual life cycle costs and the degree to which the hypothetical systems considered here reflect parameters present in maintenance training equipment systems. To the extent that they are accurate, the results indicate that the concept of the unique vs the incremental device should be an integral factor in cost comparisons of simulated vs actual equipment for maintenance training in advanced aircraft systems.

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The opinions and conclusions contained in this paper are those of the authors and do not necessarily reflect the views of the Department of the Air Force.